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ABSTRACT

This paper reviews trends in assessment in quantitative courses and illustrates several options and approaches to assessment for advanced courses at the graduate level, especially in multivariate analysis. The paper provides a summary of how a researcher has used alternatives to traditional methods of assessment in a course on multivariate analysis. The results of a survey of student ratings of assessment strategies are presented. Among the trends in statistical education are an emphasis on activity-based learning and a recognition of assessment as learning. In the multivariate analysis course, the researcher/teacher has used four different kinds of assessment: (1) structured data analysis assignments; (2) open-ended assignments that require students to develop research questions; (3) articles reviews; and (4) annotating output from computer runs. Examples of each assessment type are given. At the end of the course, the 14 students were asked to rate each strategy. Overall, the survey findings suggest that a variety of assessment strategies provides the opportunity for different kinds of feedback about the material being learned. The assessment strategies chosen by the instructor can have a direct impact on student affect about the course. Findings also show that students are willing to be creative and to try new forms of assessment. (Contains 27 references.) (SLD)

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# Approaches to Assessment in Multivariate Analysis

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**Approaches to Assessment in Multivariate Analysis**

*1. Introduction*

Recently, a student came to my office to discuss her research study in the area of sports-fitness. A master's level student, she had collected data on several leg and thigh variables and wanted to assess the relationship between these measures and later occurrence of injury among women athletes. An interesting study, certainly appropriate for a master's level thesis project. Her question? How to interpret the output. The real problem? The student wasn't sure what statistical test to use, so she decided to "click on all the buttons" to make sure she got the right test!

I know this is not an unusual situation for those of us who teach educational statistics courses. In fact, ten years ago Searle (1989) and Dallal (1990) discussed just this kind of situation in their debate on the merits of including instruction on statistical computing packages as part of statistics courses. However, while there was clearly a missing link for this student hindering her ability to move from the research question to an appropriate analysis and interpretation of the data, I feel that this scenario speaks to a larger gap between how we assess learning in statistics courses and the actual statistical competencies - knowledge and skills - that we expect our students to have after completing these courses.

For graduate students in the social sciences, coursework in advanced statistical methods should enable them to embark on a successful academic career. To do this, students need sufficient preparation in statistical methods for completion of a culminating project (thesis or dissertation) which establishes a personal contribution to their field of study, and for making continued contributions to their field through an active and productive research agenda. We need to identify effective activities and assessments that can promote learning for transfer to research experiences outside of our classrooms.

*2. Purpose*

The purpose of my presentation today is to review trends in assessment in quantitative courses and illustrate several options and approaches to assessment for advanced courses at the graduate level, particularly in multivariate analysis. Hopefully, this presentation will stimulate interest and further discussion among statistics educators, and encourage others to pursue empirical studies in this area. I present the results of a survey of student ratings of assessment strategies I've used in my own courses, including

(a) structured data analysis assignments
(b) open-ended assignments
(c) article reviews, and
(d) annotating computer output for specific multivariate procedures.

*3. Trends*

In recent years, one of the most significant trends to emerge in statistical education involves an emphasis on activity-based learning. Activity-based learning can take many forms, including cooperative group tasks, computer based problem-solving activities or simulations, or

the collection and analysis of "real," as opposed to textbook, data. One goal of these reforms is to improve statistical literacy, which is the ability to understand and discuss statistics normatively. Learning can be enhanced when students are actively engaged in a problem, and are able to structure their new knowledge in terms of their own experiences and academic interests. In my own courses, I've tried to include an assortment of assessment activities with a view towards supporting the development of statistical literacy.

Actually, I think "statistical clarity" might be a better term for what I want students to achieve in my classes, since it more strongly emphasizes several inter-related goals in multivariate analysis - clarity of purpose in research design and analysis, and clarity in articulation of results. By assessing the knowledge, skills, and abilities we feel to be important, students will be in a better position to appreciate and review their own efforts at learning. In fact, the National Council of Teachers of Mathematics (NCTM) has recently published Assessment Standards (1995) for school mathematics which are every bit as applicable to the graduate classroom as well. Their recommendations include viewing assessment as a convergence of information from different kinds of sources or activities; that assessment should motivate greater achievement; and that connections among different kinds of knowledge should be assessed.

*4. Assessment as Learning*

From the NCTM recommendations, it is clear that statistics educators need to move towards creative and authenticated approaches to assessment of student learning in statistics. Garfield (1994; Gal & Garfield, 1997) has often reminded us to use assessment as a vital part of the learning process and not just as a grading strategy. The tasks that we give our students today should result in learning that can transfer to new situations and research settings tomorrow. This goal also is emphasized in the Assessment Standards (1995) since, "assessment should be a means of fostering growth toward high expectations" (p. 1). In the multivariate classroom, the expectation typically is for students to consolidate conceptual and procedural knowledge about advanced statistical techniques. How this can best be accomplished remains an issue for consideration by educational researchers and instructors of quantitative courses.

*5. Background: Training in Graduate Statistics*

The literature on pedagogy in introductory statistics courses continues to grow (e.g. ISR special issue, April 1995; JEBS special issue, Spring 1996; Gal & Garfield, 1997), yet comparatively little information is available on how well or how much we train our graduate students beyond the introductory level. There is evidence that graduate training in statistics needs to be improved, particularly for substantive researchers whose areas of expertise may not be quantitative methods Keselman, Huberty, Lix, et al., 1998). For example, Keselman and his colleagues found that published research in respected journals in education and psychology often contains no reference to issues such as verification of assumptions, power, or effect size (1998).

Despite the fact that relatively little published work is available on assessment in advanced statistics courses such as multivariate analysis, we can build on the suggestions of statistics educators and researchers who have concentrated on introductory statistics courses in

order to inform better practice in instruction and improve learning in advanced courses. In particular, statistics educators argue for a more active involvement on the part of the student, strengthening their investment in their own learning processes.

*6. Background: Transfer*

There is still a lot we don't know about transfer of knowledge to new situations (Pintrich, 1994), yet transfer is clearly an important goal for courses in multivariate analysis. Important outcomes for an advanced statistics class are for students to understand published research literature in their field and be able to apply the principles and techniques they've learned to new and perhaps rapidly changing research initiatives and directions.

Familiar early studies by Tversky and Kahnemann (1983) and Shaughnessy (1981) showed that formal instruction in statistics did not protect people from their pre-course misconceptions in statistical reasoning or improve their ability to make informed decisions under uncertainty. Results of other studies by Fong, Krantz, and Nisbett (1986) and their colleagues (19xx) have offered some limited support for transfer of statistical training. More recently, research evidence supports the idea that conceptual knowledge plays an important role in the acquisition, development, or use of procedural knowledge (O'Connell, 1999; Rittle-Johnson & Alibali, 1999), but how the relationship between these two kinds of knowledge affects transfer to new situations needs further attention. Finally, in terms of transfer of statistical knowledge and skill to actual research activities, Keselman et al. (1998) report that "a substantial gap exists between the inferential methods that are recommended in the statistical research literature and those techniques actually adopted by applied researchers" (p. 351).

*7. Background: Valuing what we Assess*

One way we can begin to strengthen the bond between conceptual knowledge and procedural knowledge in advanced statistics is to review our own instructional practices, including the goals for intended student learning and our corresponding assessment strategies. In particular, assessment that is grounded as much as possible in real-world experiences [offers the best possibility for] can guide our teaching for transfer of statistical knowledge to novel situations and research questions. One of Garfield's principles on statistical learning is that students will come to value what they know will be assessed (1995). If we can develop our assessments so that students learn to appreciate how statistical methodologies may be applied to diverse data sets or research situations, then we clearly will be moving towards strengthening our graduate level training in advanced statistical analysis courses.

*8. Multivariate Assessment Study*

My findings provide a summary of how one researcher (the author) has used alternatives to traditional methods of assessment in a course on multivariate analysis. As the literature is sparse in this area, one way to begin to understand the impact that assessment has on student learning of multivariate techniques is by studying student reactions to particular forms of assessment. This approach is helpful for reflecting on what our own goals might be for our

students, understanding how well these goals are being met, and suggesting methods for improving both teaching and learning of advanced statistics.

This is the first course in a two semester sequence in multivariate analysis. Course topics include:

- Multiple regression (review and additional material)
- Multivariate analysis of variance and covariance
- Factorial analysis of variance
- General linear model
- Repeated measures analysis and profile analysis
- Discriminant function analysis
- Canonical Correlation
- PCA/FA

The course objectives are:

(1) develop the ability to work competently with a variety of multivariate statistical techniques;
(2) understand research literature/reports involving these techniques;
(3) use the computer (SPSS) to run and interpret the results of multivariate analyses; and,
(4) write up coherent results from these analyses.

*9. Assessments Used*

I used four different kinds of assessments during my course: structured data analysis assignments where specific questions are posed and answers found through computer analysis or follow-up hand computation when necessary; open-ended assignments which requires students to develop a research question based on a particular data set, analyzing the data appropriately for the question and the data, and interpreting/writing up a formal report of the results; article analysis which requires students to read a particular research article and answer questions based on the article; and annotating output from computer runs. Examples for each assessment type are provided below.

**Structured data analysis assignments** are those where I supply the data, and sometimes the program syntax, and ask specific questions for the students to answer. Generally, all students in the class should have the same or very similar responses to each question.

Example: Multiple Regression Review

The data consists of four variables collected on a small sample of junior high school students (adapted from Tatsuoka, 1988). The dependent variable of interest is an achievement test score in the physical sciences. A teacher is interested in studying the extent to which achievement in the physical sciences (Y) can be predicted from measures of math ability (X1), mechanical reasoning (X2), and/or creativity (X3). To begin to address the teachers concerns, we are going to run a series of three regression analyses, keeping the following questions in mind:

1. After controlling for differences in math skill within this sample of students, does mechanical reasoning significantly improve our predictions of achievement? How much more explanation of variability in the physical science measure do we achieve by including mechanical reasoning in a model that already contains math skill?

2. Over and above the explanation obtained from the first two variables, should we include the creativity test score in our prediction equation? Discuss the evidence as to why or why not. Based on all of your analyses, what suggestions/conclusions would you give the teacher in terms of variables affecting achievement in the physical sciences? What model would you recommend the teacher use for predicting achievement in the physical sciences? What concerns would you share with the teacher about the data and the results?

**Open-ended Assignments.** For these assignments, I have several data sets available for students to consider establishing an appropriate research question for and reporting on their results, including High School and Beyond; automobile fatality rate data (Judd & McClelland, 1989); a survey on attitudes/perceptions regarding distance education (King, 1999); behavioral variables related to condom use among women (Stark, Tesselaar, O'Connell, et al., 1996); relationships among different kinds of coded errors during probability problem-solving (O'Connell, 1999); and data from the evaluation of an adolescent pregnancy prevention project (O'Connell, 1997).

Example: Multivariate Project

The syllabus gives a short summary of goals for the project. I also provide an outline of what the project paper should look like. Briefly, the goals are to establish a research question appropriate to one of the multivariate techniques we are learning (and corresponding to the chosen data set), and prepare a report detailing the methods used to answer your research question and interpretation of results.

- Short, independent, research and analysis paper, limited to 5 to 10 pages.
- Written in APA style (or style appropriate for your field).
- Purpose of the project is to show me that you can understand and write intelligently about a specific multivariate technique (one of the above).
- Several data sets are available for analysis.
- If you want to use a data set from a project you are working on, you must clear it with me first. The data must have already been collected, you need permission from the PI, and any Human Subjects issues must already be addressed. I reserve the right to say yes or no to people's request to use their own data, since I want people to be successful at their particular analysis and not bogged down by potentially messy or complicated data sets.
- Project Data Information Sheet is to be completed (a downloadable form) - describes variables and how they are measured.
- Be aware that the analysis you might choose for the purposes of this course may not be the only approach for a particular data set/research question. I am interested in how you approach the particular analysis you selected.
- You will be graded on the clarity of your analysis, and its correspondence to the research question you asked for the purpose of this course.

- The appendix to your project/paper should contain the output you used for analysis, annotated to describe how you used the output to address your research question(s).

**Article analysis.** For the article review assignments, I ask the students to prepare a paper detailing the responses to several questions based on the research article.

*Article 1.* Dant, R.P., Lumpkin, J.R., and Bush, R.P. (1990). Private physicians or walk-in clinics: Do the patients differ? Journal of Health Care Marketing,10(2), 25-35. (also from Hair, et al., (1992), p. 138-152).

*Article 2.* Karacostas, D. D. & Fisher, G.L. (1993). Chemical dependencies in students with and without learning disabilities. Journal of Learning Disabilities, 26(7) 491-495.

Example: Karacostas & Fisher article

1. Purpose
2. Population/Sample - generalizing/validity issues?
3. Variables - how measured?
4. What are the research questions? What analyses were used to investigate these research questions?
5. Assumptions?
6. In Table 1, second entry is 34/38. Describe what both these values mean.
7. Explain the canonical correlation and how it relates to % variance.
8. Do you agree with their results/conclusions? Any limitations, even other than they mention? Missing information?
9. Recommend any further analyses which might be appropriate here. What would be the hypotheses for these analyses if the study was replicated?

**Annotated Output**. For these assignments, I ask students to run a particular analysis (after we had already reviewed the topic and an analysis in class), such as DFA, and to label on the output the elements necessary for understanding the results. Often, the programs may correspond to data available in the text (we used Stevens (1996) during the Fall 1999 semester). I also required them to annotate the output for their open-ended projects.

Example: Factorial Manova, data suggested from Stevens page 310, #1.

I changed some of the data points and made the data available on the webboard.

a. run the analysis.
b. annotate the output.
c. state the assumptions and how you would verify them. Also write out the null and alternative hypotheses for the HOC test and report the results of this test.
d. write a brief summary (a few paragraphs). Be sure to explain how your support or non-support of the assumptions required for Manova affect your interpretation of the results.
e. give the effect size for any significant multivariate or univariate results that you report.

*10. Student Assessment Ratings*

At the end of the course, students were asked to rate each different assessment strategy in terms of (a) difficulty, (b) appropriateness to their needs while learning multivariate statistics, and (c) how well they felt they learned using that kind of assessment (n=14). I also asked students for additional comments regarding their likes and dislikes about each assessment strategy, suggestions for how to improve the use of that strategy, and any other observations or comments they might have. In terms of establishing a course grade, the two open ended assignments (midterm and final) were 25% each; the other assignments were averaged and worth 50% total.

In the tables that follow, I present the results for each assessment strategy, and highlight the model response for each technique. Other interesting findings are highlighted as well. The median rating for each assessment technique is presented in the last row of the tables.

*9. Difficulty Ratings*

| | Structured Computer Assignments | Open-Ended Assignments | Article Analysis | Annotating Output |
|---|---|---|---|---|
| (1) Not at all difficult | 7.1% | 0.0% | 7.1% | 0.0% |
| (2) Slightly difficult but not too challenging | 35.7% | 14.3% | 28.6% | **57.1%** |
| (3) Difficult but challenging | **50%** | **85.7%** | **50%** | 42.9% |
| (4) Too difficult | 7.1% | 0.0% | 14.3% | 0.0% |
| Median rating | (3.0) | (3.0) | (3.0) | (2.0) |

*11. Appropriateness*

| | Structured Computer Assignments | Open-Ended Assignments | Article Analysis | Annotating Output |
|---|---|---|---|---|
| (1) Not at all appropriate or useful | 0.0% | 0.0% | 7.1% | 0.0% |
| (2) Slightly appropriate but not for all my needs | 14.3% | 7.1% | **35.7%** | 35.7% |
| (3) Appropriate for many of my needs | **78.6%** | **50.0%** | **35.7%** | **64.3%** |
| (4) Very appropriate for all my needs | 7.1% | 42.9% | 21.4% | 0.0% |
| Median rating | (3.0) | (3.0) | (3.0) | (3.0) |

*12. Learning*

| | Structured Computer Assignments | Open-Ended Assignments | Article Analysis | Annotating Output |
|---|---|---|---|---|
| (1) Didn't learn anything | 0.0% | 0.0% | 7.1% | 0.0% |
| (2) Learned a little bit | 21.4% | 7.1% | **42.9%** | 28.6% |
| (3) Learned enough to be comfortable with the topic | **57.1%** | **50.0%** | 28.6% | **57.1%** |
| (4) Learned a great deal - more than I would have thought | 21.4% | **42.9%** | 14.3% | 14.3% |
| Median rating | (3.0) | (3.0) | (2.0) | (3.0) |

*13. Preference Scores*

Students were also asked to indicate their order of preference among the four assessment strategies, with 1 = most preferred form of assessment, and 4 = least preferred. Average preference ratings indicated that the most preferred forms of assessment were the structured computer assignments ($\bar{X}$=2.00), followed by annotating the output ($\bar{X}$=2.31), use of open-ended assignments ($\bar{X}$=2.38), and article analysis ($\bar{X}$=3.15). Yet in terms of difficulty level, appropriateness, and learning ratings, the open-ended assignments actually received the better ratings overall. Approximately 86% of the students found the open-ended assignment challenging; 93% found the open-ended assignment appropriate for some or all of their needs; and 93% reported learning enough either to be comfortable with the topic or that they learned more than they would have thought.

*14. Why the switch between preferences and ratings?*

One explanation for the preference switch may be the time-involvement required for the open-ended assignment. Basing data analysis within the context of an actual research problem, as in the open-ended assignments, can be a strong motivator for students, and the experience requires the student to become an active participant in their own learning process. The structured assignments, with questions already posed by the instructor, provides greater direction and may have less cognitive load so in a sense might be considered easier. However, these structured assignments allow less flexibility and creativity in working towards a solution. Their purpose is very different from that of the open-ended assignments - although interpreting output is an important step towards interpretation and the convergence of procedural and conceptual knowledge.

*15. Student Comments*

Structured Computer Assignments:

- "These smaller assignments helped me to better get into the topic, realize where I have difficulties and learn from your comments."
- "Doing this type of assignment first helped me with the less structured assignments later."
- "Written feedback was very useful."

Open Ended Assignments:

- "This was difficult, but very necessary for us as competent researchers."
- "The open-ended nature of the assignments "forced" me to think about the bigger conceptual issues. It helped to apply the info to real-life examples, like I will be doing with my dissertation."

- "Excellent, the openness addressed my own misconceptions."

Article Analysis:

- "This assignment was time consuming b/c there was a lot of English vocabulary I have not been exposed to."
- "Would have liked to instead answer all of the questions and then discuss the article in class – but we didn't have enough time."
- "The topic was not of personal interest."

Annotating Output

- "This assignment was not clear to me so I did not like it or see its usefulness."
- "Excellent strategy; helped to really connect concepts to application."
- "We should be asked to annotate outputs more frequently."

*16. What I've learned*

Reflecting on student perceptions of the assessment strategies we use in our classes is a good first step towards improving our instruction and making our assessments more meaningful. Since our students will most likely be using the multivariate techniques they are learning as they begin their own academic careers, it is important not to loose site of their needs, and to ensure that accurate learning has occurred. In addition, the process of evaluating student perceptions of classroom activities models good strategies for potential future teachers of a complex topic such as multivariate analysis.

In general, my findings suggest the following:

- A variety of assessment strategies provides the opportunity for different kinds of feedback about the material being learned.
- The assessment strategies we choose (and it is <u>our</u> choice, so we have to do it responsibly) can have a direct impact on student affect about the course. Since we would like students to get enjoyment from their effort - particularly for understanding their own data/research - this affect factor can't be ignored.
- Students are willing to be creative, try new forms of assessment, and also are eager to help us learn what works best.

For my own course, this process has helped me think about how to refine and refocus my assignments for better student learning outcomes.

- Need additional, and perhaps briefer structured assignments, to provide an opportunity for more feedback.

- *Even with open-ended assignments, I can provide better guidance on what my* expectations are. A project time-line, perhaps with a checklist for project milestones (research question, brief lit-review, analysis method, etc.) and a variable summary check list might enhance the learning process.
- I think article critiques are important, and often form a part of comprehensive examinations. However, suitable class time needs to be reserved for review of these articles as a class. Perhaps consider group presentations of different articles.
- Annotating output and writing up corresponding results sections can mimic the self-explanation strategies which are so important to good learning (Chi, et al., 1989, 1994).
- Still working on the best "mix" of assessments, but this personal study has provided me with a wealth of information on where I can improve my own instruction and assessment practices.
    - individual or group projects (Dietz, 1993; Cobb, 1992; Garfield, 1993; Holmes,1997; O'Connell, 1997)
    - poster session displays (Denson, 1992)
    - oral assessment (Joliff, 1997)
    - creative multiple choice (Wild, 1997).

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